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Thirty Years' Evolution of Technological Capabilities and Competitive Advantage in a Chinese State-owned Equipment Manufacturer: A Corporate Governance Perspective

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Abstract: This paper traces CNEGC's technological development of "introduction-imitation-innovation" in the past thirty years, which is the top state-owned equipment manufacturer in China, shows how its manufacturing capability and innovation capability improved, and examines the institutional and environmental factors which can explain these changes. Our study indicates that integrating efficient technological learning and sustainable right R&D is a vital path for China's State-owned equipment manufacturers as "latecomers". Perfect corporate governance, improving finance system, and the globalised vision and aspiration of CEO's play a crucial role in it.
Keywords: Technological capability, Competitive advantage, Corporate governance, Equipment manufacturer, Case study

1. Introduction

In the past 30 years, equipment manufacturing industry in China improved its manufacturing capability greatly through different ways of technology acquisition. But the asymmetry between strong manufacturing capability and weak technological capability constraints its international competence (Liu 2002). Equipment manufacturing industry is one of the strategic basic industries embodying a nation's competence, which mainly provides large-size equipments for metallurgical, power, chemical, and other major industries. Chinese equipment manufacturers' general technological capability lags 15-20 years behind the multinational leaders. As latecomers, Chinese manufacturers can buy the equipments, even some manufacturing technologies. But acquiring dynamic imitation capability and innovation capability is a continuously accumulative process instead of a one-off deal. Moreover, no matter how debatable the pattern of 'introduction-imitation-

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innovation' has been, it is crucial for Chinese equipment enterprises to get out of the vicious cycle of dependent introduction and static technological capability, and achieve dynamic technological capabilities and latecomer's advantage. State-owned enterprises (SOEs) are still dominant players in China's equipment manufacturing industry. So, this paper chooses a state-owned equipment manufacturer for case study.

In order to narrow the technological gap with developed countries, from 1979 Chinese government has been seeking an efficient corporate governance system, e.g. contract responsibility system, corporate system and joint-stock systems, to motivate SOEs to improve their technological capability and competitive advantages in both domestic and international markets (Nolan 2001; Tylecote and Cai 2004）. But until 2001, compared with privately-owned firms (POEs), SOEs' performance has been volatile and generally poor. Moreover, as POEs became stronger competitors, SOEs' sales and profit suffered accordingly (Nolan and Zhang 2002; Cai and Tylecote 2005). But after China's entry into WTO in 2001, the corporate governance of SOEs has been changing greatly, i.e. structure of ownership, selection of management, assessment criteria, forms of penalties, etc. At the same time, SOEs' technological capability and general performance have been improving. From 2002-2007 SOEs' sales and profit increased 16.1% and 33.7% on average per year, meanwhile the absolute number of firms decreased by around 10,000 annually. How can we explain such phenomenon? Is it a result of monopolization or development of technological capabilities or improvement of corporate governance?

This paper traces the technological development history of one large-scale SOE, China National Erzhong Group Co. (hereto CNEGC). Specifically, we discuss how the state-owned equipment manufacturer's technological capabilities evolve over time, and explain its distinctive performance change from the corporate governance perspective. Data collection was conducted in May-September 2007, through intensive face-to-face interviews with CNEGC's top management, technology centre, manufacturing branches, marketing department and subsidiaries. We also drew on CNEGC's yearbooks (1958-2006) for complementary insights and statistical data.

The main research questions are:

- How can we depict the different stages of technological capabilities in CNEGC?
- How was CNECGC able to improve its technological capabilities and acquire sustainable competitive advantage, given its position as a latecomer operating in an increasingly open and competitive environment?
- What role have institutional factors, more particularly corporate governance (in the broadest sense), played in the evolution of CNEGC's technological capabilities?

The rest of the paper is arranged as follows. Section 2 reviews the literature and proposes our theoretical framework. Section 3 describes the technological capabilities developed in CNEGC at different stages along the path of technology introduction, imitation and innovation. The firm's general performance was also tracked longitudinally. Additionally, it demonstrates the efficient path to developing innovation capability through two examples. Section 4 analyzes the effects of corporate governance and finance on technological development, especially on development of innovation capabilities. Section 5 concludes the paper.

2. Literature review and analytical framework

In the era of globalization and increasing uncertainty, the fundamental question in strategic management is how firms can obtain unique competence and acquire sustainable competitive advantages (Rumelt, Schendel and Teece 1994). Porter (1985) and Barney (2002) divided the competitive status of enterprises into three types: competitive advantages, competitive parity and competitive disadvantages. The enterprise with the competitive advantages generally outperforms those with only competitive parity. Here performance is defined through comparison between value produced by the productive assets and the value expected by the owners（Coase 1937; Alchian and Demsetz 1972; Jensen and Meckling 1976）. In this paper, sales and profit are used to indicate firm performance.

Technological capability refers to the ability to make effective use of technological knowledge. It is the major determinant of industrial competitiveness (OECD 1996; Schacht 1997; Kim 1999). "Latecomer's advantage" theory indicates that the latecomers in developing countries usually develop their technological capabilities first through introducing technologies, and then building innovation capabilities based on technological learning and imitation（Nelson and Winter 1982; Nelson 1987; Dosi 1988; Lall 1992; Wu and Xu 1995; Kim 1999; Amsden and Chu 2003). At the introduction stage, the technologies that latecomers face are given; their main tasks are hence utilization. So, at such moment latecomers' technological capabilities are mainly *static*, which are based on existing technology or technology-using skills（Ariffin and Figueiredo 2001）. At the later stage of imitation, latecomers can legally duplicate and/or illegally counterfeit, and improve existing technologies - they have duplicative imitation capabilities (Bell and Pavitt 1993; Kim 1997). If firms have the ability to identify scope for efficient technology utilization, to extend and deepen their own capabilities or draw selectively on others to complete their own capabilities, they will undergo the process of innovation capability building in which firms start to generate emerging technology that cannot be acquired (competitively) from either local or foreign sources. At the later two stages, the firms' technological capabilities are *dynamic* - the abilities to create new technology or change and improve existing technology. Moreover, in a given technological paradigm (Dosi 1982) latecomers have at least two opportunities in the field of mature technologies, i.e. improving mature technologies and "re-inventing" mature technologies (Perez and Soete, 1988; Utterback, 1994; Gao, 2003).

Drawing upon Fransman (1984), Katz (1987), Dahlman and Westphal (1987), Lall (1987, 1992), Yam et al (2004), this paper evaluates technological capabilities in five dimensions: Investment Capability, Product Capability, Production Capability, Organization Capability and Strategic Capability. *Investment Capability* includes skills needed to identify, evaluate and acquire technology for new products/facilities or for upgrading the existing technological base. It determines the capital costs and the appropriateness of the technology selected. *Product Capability* contains skills required to produce products or improve product specifications, such as parts assembly and improvement in product design for cost-effectiveness and product diversification. *Production Capability* decides the productivity of product making. It assesses firms' ability of process management, quality management and efficiency management. *Organization capability* evaluates firms' ability to make changes in organizational structure, ownership and reduction in hierarchy, bureaucratic attitudes to

cope with technological change. *Strategic Capability* refers to the ability to identify internal strengths and weaknesses and external opportunities and threats, formulate plans according to corporate vision and missions, and adjust the plans for implementation.

There is increasing interest in the effects of corporate governance on technological development in developing countries, particularly the governance of SOEs. The effect of corporate governance on firm performance has been recognized as early as Berle and Means (1932). It later became a long-standing research area covering various disciplines (Jensen and Meckling 1976; Jensen 1986, 1993; Demsetz and Villalonga 2001). However, earlier research mainly focused on the direct correlation between corporate governance and performance. Few referred to the effects of corporate governance on technological development and then on performance. Lazonick and O'Sullivan (1996, 2002), Lazonick (2005) and O'Sullivan (2000) put forward a general institutional framework to analyze the technological development of innovative firms which considered corporate governance and finance (CG&F).

Tylecote and Conesa (1999), Tylecote and Ramirez (2006) and Tylecote (2007) developed a more specific theoretical framework on the effects of CG&F on firms' technological development. Corporate governance is the set of processes, customs, policies, laws and institutions affecting the way in which a corporation is directed, administered or controlled (OECD, 2004). The central problem in CG&F is *information asymmetry* – in finance, between receivers and providers, and in corporate governance between *agent* and *principal*: management and owners, if these are 'outside' shareholders or the state (Jensen and Meckling, 1976). The managers of SOEs are responsible to officials who are themselves not principals, but agents of more senior officials. Such second-order agency must increase the resulting distortions of behaviour. These will particularly affect activities directed at technological development, because many of their immediate outputs have *low visibility* from the point of view of principals (and financiers). Their costs however are highly visible. If the principal (or financier) is 'dis-engaged' from the firm, therefore ill-informed about it, the manager will feel under pressure to spend sub-optimally on such activities – and perhaps more on relatively high-visibility activities. Such pressures will be the greater, the shorter the manager's time horizon in the job (Tylecote and Ramirez, 2006). Two other aspects of corporate governance are relevant: (i) How much *expertise* do owners have regarding the technologies and markets relevant to the firm? *Industrial expertise*, combined with engagement, gives good understanding of the value of technological activities. (ii) How are *stakeholder spill-overs* from technological change managed? Spill-overs are costs and benefits to stakeholders, mainly employees, and related firms. *Stakeholder inclusion* involves cooperative efforts to make improvements.

The research of Tylecote and Cai (2004), Cai and Tylecote（2005）, Nolan and Zhang（2002）showed that these insights are relevant, with some adaptation to the Chinese context. The problem of agents (managers) answering to agents (government officials) and the continuously shifting supervisory roles among different government authorities, discouraged *shareholder engagement* to technological development. The traditional SOE top manager's career path is essentially that of an official, chosen for his position by other officials and looking to be moved before long (perhaps five years) into a higher position, in a larger firm or a ministry. The time horizon in the job is therefore short, and while in it, the need is to make a good impression on senior officials – themselves subject to regular rotation and unlikely to 'engage' closely with the firm. Worse still, some

of these managers have been 'parachuted' into the organization, mostly with limited *industrial expertise*, nor do they have the incentive to learn, due to their short time-horizon. Moreover, if SOE mangers perform badly, the traditional way to handle this is to reallocate them to a similar position in another firm (under the supervision of the same ministry) – managers do not have to bear the result of their mistakes, hence the pressure for shareholder value maximization (particularly in the long run) is missing.

Although agreeing with their conclusions, we propose that there are two more key characteristics in the governance (and finance) of Chinese SOEs that have been influential to their capability development. First of all, the over-reliance on the single criterion of short-term profit in performance measurement has limited the incentive for firms to develop sustainable technological (innovation) capabilities. As for finance, Cai and Tylecote (2005) argue that although SOEs are generally ill-governed, they are meanwhile well-financed. Yet the financial situations of SOEs have undergone significant changes since the mid 1990s. The traditional financiers of Chinese SOEs have been state-owned banks who are prevented by law from engaging with funded firms. Until 1995, their roles as channels of government subsidies meant they had to fund any authority-appointed firms (mostly SOEs) regardless of their performance (Ding, 1999). SOEs at that time were blessed with funds and exempted from obligations to fulfill strategic investment. However, we found that following the introduction of 'Commercial Bank Law' and general transformation of state commercial banks, SOEs suddenly woke up to find themselves no longer financially privileged. We argue that at this stage the lack of funding has also hindered their development of technological capability.

Based on the above analytical framework and observations, we go on to study the longitudinal evolution of CG&F in a typical Chinese SOE - CNEGC, and their effects on the development of technological capability. Particularly, we strive to understand the new patterns and progress of capability development in the firm since China's entry into WTO in 2001, by looking at changes in its CG&F.

3. Development of technological capabilities in CNEGC

3.1 Basic information of CNEGC

CNEGC was established in 1993. Its predecessor State-owned No.2 Heavy Machine Factory was founded in 1958 in a heavy-industry hub in Western China. CNEGC is now a state-owned 'backbone' enterprise making key technical equipments for Chinese national economy and national defense construction. It is one of China's 21 domestic 'heavy machinery bases' – key manufacturers. By the end of 2006, it had over 12,900 employees and more than 1,200 R&D personnel. Its main products include large-size complete-set metallurgical equipments, large-size castings and forgings, etc. The market shares of its main products are among 45% to 60% in China. It also sells to developed countries including USA, Germany, UK and Japan, etc.

3.2 Developing stages of technological capabilities and performance of CNEGC

According to the literature review in Section 2 and the process of technological capability building, since 1979 CNEGC's technological development has undergone three stages, namely Technology introduction & Dependent Manufacturing (1979-1989: stage 1), Duplicative Imitation & Collaborative Manufacturing (1990-2000: stage 2), and Indigenous

Innovation & Integrated Manufacturing (2001-present: stage 3).

3.2.1 Technology Introduction & Dependent Manufacturing (1979-1989)

This stage parallels the early period of China's reform and opening up. Due to sharp reduction of government plan after 1979, CNEGC for the first time had to face the market's demand and competition. Therefore it adjusted the product and service structure accordingly, e.g. expanding product mix from large-size complete-set equipments to small complete-set equipments and industrial and mining fittings, and expanding its target market segments. In order to improve its product lines and production capability, CNEGC took advantage of the opening up opportunities given to privileged large SOEs, and introduced up-to-date manufacturing technologies and equipments from foreign firms.

Table 1 Technological capabilities of CNEGC at Stage 1 (1979-1989)

	Important events
Strategic Capability	Authorized by State Council to open to the outside world as the earliest group of SOEs in 1979
	Introducing foreign up-to-date manufacturing technologies and machinery to develop product and production capability
	Adjusting the structure of product and service to adapt to market system, expanding from large-size machinery to small-size complete-set machinery and accessories
Investment Capability	Introducing foreign manufacturing technologies and machinery through licensing trade in large bulks
Product Capability	Imitating mature products, e.g. 10,000t polydirectional hydraulic press, 2450mm 4-roller reversible hot mill, 3300mm plate mill, etc.
	Manufacturing of products designed by foreign firms or other domestic firms, e.g. 2,050mm hot tandem mill(cooperated design with SMS, Germany), 1,550mm plate blank tandem mill(cooperated design with Kobe Steel, Ltd., Japan), etc.
Production Capability	Assimilating acquired technologies and renewing equipments to improve production capabilities
Organization capability	Establishment of Standards Committee, Heavy Machinery Design & Research Institute and Large-size Casting and Forging Research Institute
	Sending technicians abroad for training and collaborative design

At Stage 1, the typical technology introduction was through technological licensing : (i) 1978-1988, manufacturing technologies of hot die forging press, horizontal forging press and equipments from Eumuco Co. (ii) 1982-1986, manufacturing technologies of large-size casting and forging products from Japan. (iii) 1984-1991, 400mm artificial crystal autoclave equipments from USA.

Corresponding to with technology introduction, the main patterns of manufacturing and products were: (i) imitation of mature products. (ii) CNEGC responsible for production while foreign partners in charge of design or general technology.

CNEGC realized the need to ensure product quality and improve its process technology. So it took the following measures: (i) implementing the standards used by foreign industrial leaders and attempting to establish its own product-oriented standard system. (ii) Setting up standard organizations including the Standards Committee and Standards Office which was in charge of daily operation. (iii) Founding the Total Quality Management (TQM) Office. (iv) Establishing Process Technology Office which was lead by the chief engineer and in charge of cold and hot process technology. (v) Establishing Heavy Machinery R&D Institute and Large-size Casting and Forging Research Institute, intending to re-design some mature products to match local market needs. (vi) Sending technical staff to train and

jointly design abroad, from 1979 to 1988 448 were sent.
CNEGC spent 5-10 years to assimilate the above introduced manufacturing technologies and equipments. As a result: (i) it possessed the necessary ability to cooperate with the foreign firms on design and production at Stage 2. (ii) Its process technology was continuously improved. For example, the large-size complete-set castings and forgings produced by CNEGC for introduced 600MW thermal power unit reached top international standards, symbolising its achievement in hot process technology. (iii) Its sales growth and profit were ensured, as shown in Fig. 1 and 2.

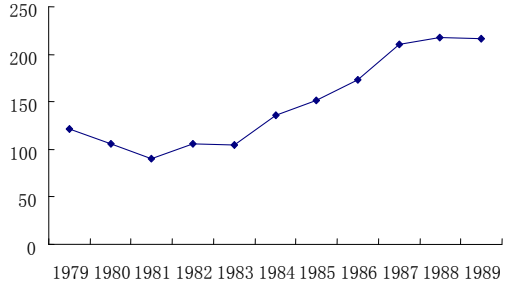

Fig. 1 Sales of CNEGC, 1979-1989（million RMB）

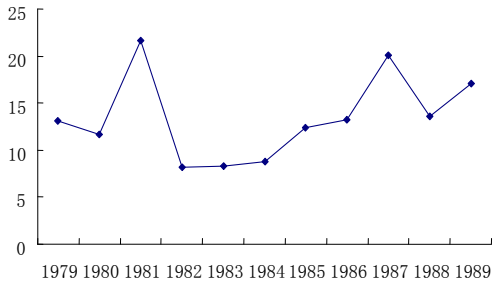

Fig. 2 Profit of CNEGC, 1979-1989（million RMB）

3.2.2 Duplicative Imitation & Collaborative Manufacturing (1990-2000)

Since 1990, competition from POEs increased quickly in the smaller machinery sub-sectors (relatively easy to enter) and the heavy equipment manufacturing industry shrunk due to government macro-control. In order to maintain its sales and profit, CNEGC adjusted its business policies, i.e. 'to focus equal on large complete sets as well as small/medium-size equipments; on long-term strategic and short-term tactic products, on popular and unpopular products'. As Table 2 shows, its technology strategy also shifted from 'Technology introduction & Dependent Manufacturing' to 'Duplicative Imitation & Collaborative Manufacturing'. On the one hand, it jointly designed and manufactured mature products with foreign firms to develop product and production capabilities; on the other hand, it re-designed mature products for local market demand.

Table 2 Technological capabilities of CNEGC at Stage 2 (1990-2000)

	Important events
Strategic Capability	Joint design and collaborative manufacturing with foreign firms to develop product and production capability
	Re-design mature products for local market demand
Investment Capability	Decrease in R&D investment
	R&D endeavor mainly in improvement of large-size steam turbine cylinder and aviation die forging
	Stagnant upgrade and improvement of manufacturing equipments
Product Capability	Producing mature products with foreign firms, while foreign firms frequently in charge of general technological design, e.g. 155t RH/AHF molten steel refining equipment, 1450 hot rolling strip steel complete-set tandem mill, hot rolling strip steel complete-set equipment, 2250 hot tandem mill
	Re-designing and producing mature products to match local market demand by CNEGC, e.g. 3500mm tandem mill, KP8000 hot die forging mill, etc.
Production Capability	Obtaining necessary certificates for operation, e.g. ISO9000, ASME, U and U2 for pressure vessel, ZC, LR, ABS, GL, DNV, NK, BV, RINA for large-size marine casting and forging
	Adopting important and advanced foreign standards, e.g. SN200, EN, DIN, JIS
	Absorbing and learning up-to-date technological information through joint design and collaborative manufacturing

Organization capability	Establishing Technological Centre to manage technological innovation in 1999 Restructuring Quality Department in 2000 Cooperating with Tsinghua University, Yanshan University, etc. in product and process improvement

Table 3 shows, from 1991 to 1997, CNEGC's equipment modification and renewal slowed down, and its R&D focused on imitation of the technologies for making large-size castings and forgings.

As for product design and manufacturing, CNEGC resorted to joint design and collaborative manufacturing with foreign firms based its relatively strong manufacturing capabilities. Different from stage 1, at stage 2 the foreign firms usually took charge of general technology, and CNEGC no longer only specialized in manufacturing but also undertook detailed design and major manufacturing tasks. It means that CNEGC had developed irreplaceable production capability and had gradually improved its process technology. Besides, CNEGC re-designed some mature product for local market needs. Among these, in 1998 CNEGC independently designed, produced and installed a longitudinal shearing unit for Baoji Petroleum Steel Plant , such bundled project involved integrated production of mechanical, electric and hydraulic equipments, and can be regarded as a milestone for its technological breakthrough.

Table 3 Equipment modification and renewal of CNEGC, 1991-1997

Item \ year		1991	1992	1993	1994	1994	1996	1997
Among which	Number of modification	34	6	14	6	4	6	7
	overall modification	8	2	5	3	2	2	1
	Electric modification	11	3	8	2	1	4	4
Number of renewal		38	25	23	8	5	2	2

In order to meet the strict requirements of the cooperators in quality and process, CNEGC took the following measurements: (i) Continuously improving process technology and design capability. It formulated a series of process management protocols to ensure scientific, programmed, and standardized process management. (ii) Actively adopting up-to-date foreign standards, such as Germany SN200 \ EN \ DIN, Japan's JIS and its cooperators' own standards. (iii) Strengthening the role of Quality Department for quality inspection and management. It successfully passed ISO9001 Quality System Certification and a number of other international quality certifications. Especially, its large-size marine castings and forgings got certified in eight countries, including UK, US, Germany and Japan. (iv) Developing Industry-University link through cooperation with top Chinese universities (for example, Tsinghua University) and research institutes. (v) Setting up Technology Center to take charge of technological innovation management in 1999.

However, due to lack of control over the key technology, CNEGC did not manage to profit from its endeavour. As Mr Zeng, vice general manager, said in the interview, at Stage 2 CNEGC did 80% of the job but only received 20% of the profit. As Fig. 3 and 4 shows, although its sales maintained above a certain level, its profit fluctuated frequently and sometimes was negative.

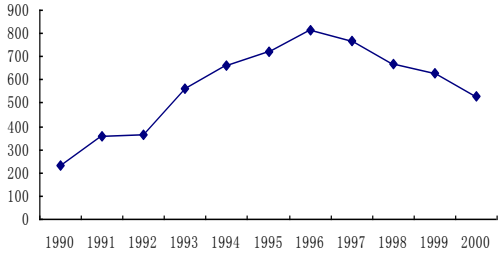

Fig. 3 Sales of CNEGC, 1991-2000（million

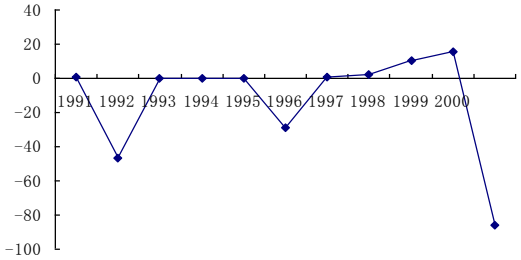

Fig. 4 Profit of CNEGC, 1991-2000（million

3.2.3 Indigenous Innovation & Integrated Manufacturing (2001-)

After China's entry into WTO in 2001, as China increased investment to the metallurgy industry and implemented active and steady monetary policy, the heavy equipment industry obtained a good development opportunity. It was most important for CNEGC to take advantage of this opportunity to improve its performance and acquire sustainable competitive advantage. In order to do that, its top management set out its technology strategy from 'Duplicative Imitation & Collaborative Manufacturing' to 'Indigenous Innovation & Integrated Manufacturing' through developing new products according to the changes in industrial policies and international and domestic markets.

Table 4 Technological capabilities of CNEGC at Stage 2 (1990-2000)

	Important events
Strategic Capability	Indigenous innovation & Integrated manufacturing
Investment Capability	Exploiting new products Selectively introducing foreign up-to-date technologies Prospectively developing new technologies concerning exploitation of marine resources
Product Capability	Exploiting and commercializing a series of new products protected by patent Indigenous design and manufacturing of up-to-date mature products, e.g. complete-set 5m-thick plate rolling mill, 3,500mm-thick plate rolling mill, 1,450mm hot coil box equipment of hot tandem mill, 1,750mm hot tandem mil, complete-set 2250 hot tandem mill exporting to Poland, etc. Forming product line to take charge of general technology in large-size complete-set equipments
Production Capability	Established standards of machinery production techniques and revised technological standards Increasing funds in nc machines Implementing four important technological transformation programs funded by plenty of finance Starting the indigenous design and manufacturing of 80000-ton large-size die and forging pressing machine in Dec. 2007, which is the biggest in the world.
Organization capability	Adjusting the organizational and functional structure of Technological Centre, integrated the five research institutes into Technological Centre as its subordinate bodies Propellent in the national and industrial standards of heavy machinery Establishing China's first patent incubator base and commercializing patented products

As shown in Table 4, of CNEGC quickly adjusted its investment priority from diversified development in stage 2: (i) Focusing on new product exploitation. (ii) Accelerating equipment renewal and modification to support the exploitation of new products. (iii) Integrating internal and external recourses to form product line, endeavoring to replace foreign firms to be in charge of general technology in large-size complete-set projects. (iv) Selectively introducing foreign up-to-date technologies, e.g. cold rolling technology, manufacturing technology of HP-IP rotor for supercritical unit, nuclear power technology, and wind power technology. (v) According to global technological development trends, initiating exploration of new technologies and products in marine resources exploitation. As

Fig. 5 and 6 show, at this stage, R&D investment in CNEGC has continuously increased, and the number of patent applications rose in general and the number of invention application also increased markedly. Especially, the number of invention applications was much higher than utility model applications in 2006 and 2007, showing improving innovation performance.

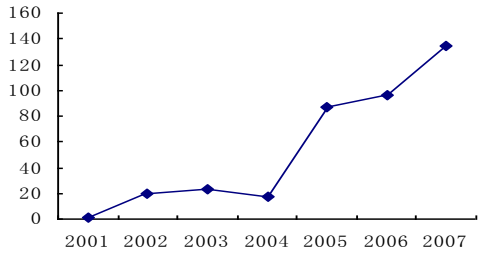

Fig. 5 R&D of CNEGC, 2001-2007(million RMB)

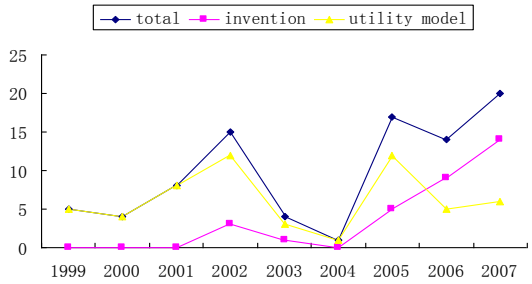

Fig. 6 Patent application of CNEGC, 1999-2007(piece)

Benefiting from efficient R&D, CNEGC indigenously developed and patented a series of new products, which is a good indicator of innovation capabilities. Notably, the success of low-carbon upper rim castings for Three Gorges turbine and 600 MW supercritical steam turbine cylinders made CNEGC leader of large-size castings and forgings in China. Its 12% Cr-type HP-IP rotor for ultra-supercritical power unit also ranked top in the world in material and process technology. In December, 2007, CNEGC started an 80,000t Large-size Die Forging Press project, which is designed and produced indigenously. In three years it will be finished as the largest press in the world.

At stage 3, CNEGC began to take charge of general technology and integrated manufacturing. The typical events were: (i) design and production of 1250mm hot tandem mill, showing that CNEGC has become one of the top firms capable of integrating mechanical, electrical and hydraulic technologies in large complete-set metallurgical equipments. (ii) design and production of 1450mm hot tandem mill, meaning that CNEGC has become one of the few firms capable of indigenous design and manufacturing of wide strip mill. (iii) Receiving two orders of hot tandem mill meant that it has become the general contractor of hot tandem mill. (iv) The order of 1700mm hot tandem mill showed that it began to take charge of integrated mechanical, electrical and hydraulic design and manufacturing in cold rolling mill for the first time. It also began to design and produce internal and external cylinders and full set of valves of 600MW to 1000MW Ultra-supercritical units for other firms. Meanwhile, CNEGC has risen from the subsidiary position in foreign cooperation and started to play a more equal role in joint design and collaborative manufacturing, in which its 5000mm heavy plate mill in collaboration with SMS was the first heavy plate mill and was called “King of Mills” in the world.

As for export of large-size equipments, CNEGC successfully sold its largest (5500 mm) vertical mill to Mitsubishi, and its export of large-size complete-set metallurgical equipment (a high-technology and high-value-added form of export) to Europe started with a 2250mm hot tandem mill to Poland. Its main customers extended to well-known multinationals in US, Germany, UK, Japan, and other countries, including firms such as Hitachi, which have been providing it with technology and equipments at the first two stages.

In order to ensure R&D efficiency and to develop innovation capabilities, CNEGC took the following measures: (i) Strengthening technological innovation management. It adjusted

the organization and function of its Technology Center by integrating the 5 key research institutes of process technology, measurement technology, heavy equipment design, and information technology, etc. It also founded specialized institutes to develop capabilities in the high-tech heavy pressure vessels and nuclear power product sectors. More importantly, it formulated and implemented strategic goals and priorities for medium/long-term technological development according to the technological trends and market demand in the international heavy machinery industry. (ii) Carrying out a series of important technological improvement with heavy investments up to 1.2 billion RMB[4] each. (iii) Focusing on the improvement of advanced cold process technologies. (iv) Zealously taking part in the industry-standard formulation and continuously improving enterprise standards. At this stage, it was chosen to lead the Provincial Process Technology Management Committee and took a chief role in the Chinese Association of Large-size Casting and Forging for Heavy Machinery, and chaired the Technology Standards Committee of Large-size Forging and Casting in China. At the same time, it constantly improved its own standards, including formulating process standards for machinery manufacturing and revising its 11-volume technological standard. (v) Emphasizing intellectual property management. It established China's first patent incubator base. In 2004, its key technology-'coreless coil box' was granted Chinese Excellent Patent Award.

With the development of technological capabilities, CNEGC's performance maintained a sustainable increase, which was never seen before. As Fig. 7 and 8 show, from 2001 to 2007 its sales increased by 7 times to 5772.6 million RMB and profit by more than 500 times to 560.38 million RMB – each boasting an average rate of 39.22% and 202.03% annually.

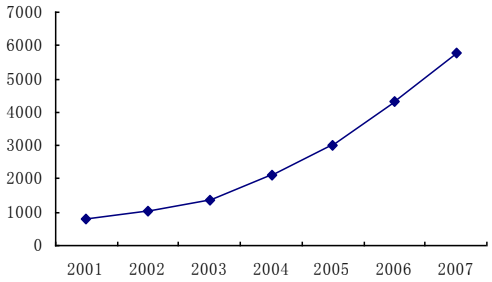

Fig. 7 Sales of CNEGC, 2001-2007(million RMB)

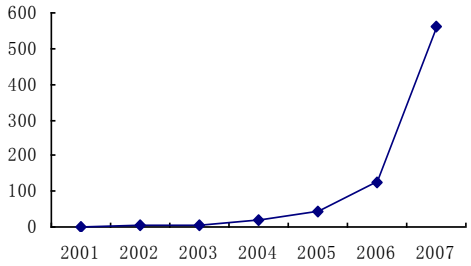

Fig. 8 Profit of CNEGC, 2001-2007(million RMB)

3.3 Developing path of innovation capability in CNEGC

3.3.1 General analysis

The technological development of CNEGC shows that technology paradigms do exist in the equipment manufacturing industry during a given period, and it is possible for 'latecomers' like CNEGC to develop innovation capabilities through integrating efficient technological learning and sustainable right R&D. On the one hand, it is efficient learning that gives 'latecomers' the opportunity to accelerate their own technological capabilities and catch up with 'first movers'. Therefore even if they have possessed certain innovation capabilities, it is still crucial for 'latecomers' to actively learn and exploit external knowledge. On the other hand, technological learning itself does not naturally bring the

[4] 1 USD≈684 RMB in July 2008

'latecomers' the ability to create new technology or knowledge. In fact, there is usually a time lag when 'latecomers' learn and imitate the leader's technologies - with the accelerating speed of current technology and product update and diffusion , there are fewer opportunities for 'latecomers' to acquire 'latecomer's advantage' through technological learning. Especially, leading firms in developed countries are now more and more serious about preventing technology spillover through foreign direct investment (FDI) and technological trade. In the situation of globalization, they are taking strict control over core patents and key know-how to sustain 'first-mover advantage'. Therefore it is advisable for latecomers to develop innovation capabilities through sustainable right R&D - no matter in the forms of improving mature technology or 're-inventing' mature technology - according to global technological trends and market demand.

3.3.2 The case of large-size steam turbine cylinder: an example of improving mature technology

In May 1982, in order to improve its technological capabilities in hot-process, CNEGC introduced large-size casting and forging technology and manufacturing equipments from Japan Steel Works Co. With a decade of technological learning and imitation, CNEGC acquired the manufacturing technologies of 125MW, 300 MW, 600 MW sub-critical steam turbine cylinders. Its quality met the standards of several multinationals including Hitachi, and its customers expanded from domestic firms to Siemens, GE, and Hitachi, etc. Till 2001 CNEGC has sold more than 200 sets of steam turbine cylinders domestically, and it has dominated more than half of the Chinese market. The growing cylinder export to world-level leaders means that its capabilities in the related areas have been accepted by these firms.

Due to reduction in coal consumption and improvement of power generation efficiency, the supercritical and ultra-supercritical steam turbines have gradually become the mainstream products of steam turbines. However, the production requires high quality material and process technology. Since 2002, three China's most famous steam turbine manufacturers have acquired the manufacturing capacity of supercritical and ultra-supercritical 600 MW and 1000 MW steam turbines through introducing and absorbing the relevant technology from overseas. It posed a vital challenge for CNEGC to meet the emerging domestic (and foreign) market needs by further improve its hot process capability.

How can this be done? CNEGC was faced with the alternatives of re-introducing up-to-date foreign technologies or increasing R&D to improve the process capabilities based on its existing technological capabilities. It chose the latter and took the following measures: (i) Its casting plant formulated the technological development plan of large-size casting process, and implemented it in 2002. (ii) Increased R&D in the new materials and technologies of supercritical and ultra-supercritical steam turbine cylinder, high pressure rotor, and welding. (iii) It revised its process procedure regulations and strengthened process-oriented quality control. In 2002 the Casting Plant put forward a creative quality management concept-'one-attempt success and zero tolerance for substandard pieces', and developed efficient assessment criteria for each step of the process as part of process-oriented quality management. (iv) Improved incentive mechanism was introduced in innovation projects and success was generously rewarded. (v) It dynamically integrated internal resources and initiated organisational changes to match the requirements of technological development. In September 2005 CNEGC transformed the Testing Workshop

of Large-size Casting and Forging Institute into Special Casting Workshop of Casting Plant. In September 2006, CNEGC set up its Casting Company-a legal entity, based on the former Casting Plant.

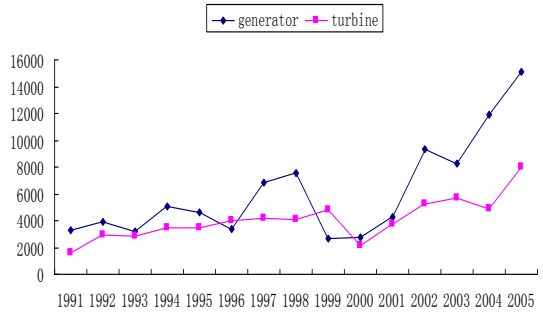

Fig. 9 Casting output of generators and turbine of CNEGC, 1991-2005 (MW)

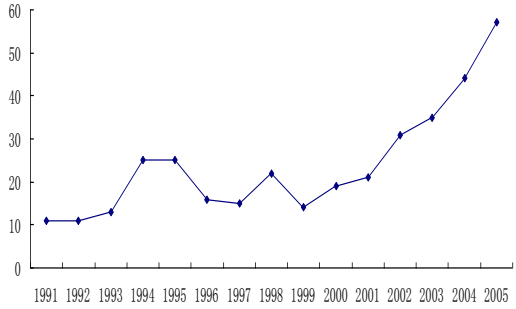

Fig. 10 Cylinder output of CNEGC, 1991-2005 (set)

Thanks to sustainable R&D and efficient innovation management, CNEGC completed the casting model of 600MW supercritical turbine cylinder in 2002, and the casting model of large complete-set gas turbine cylinder in 2004, both the first of their kinds in China. In 2005, CNEGC successfully produced supercritical and ultra-supercritical high pressure turbine cylinders and began to supply the aforementioned domestic famous firms. The technological development of turbine cylinder in CNEGC shows that it has acquired the dynamic indigenous innovation capability and has caught up with the current state of large-size castings in the world through sustainable right R&D based on technology introduction and imitation. Fig. 9 and 10 show the casting output of generator, steam turbine and cylinder in CNEGC from 1991-2005.

3.3.3 The case of hot tandem mill: an example of 're-inventing' mature technology

Hot tandem mill is the key equipment in metallurgical production lines, which is the leading product of the CNEGC. To acquire the design and manufacturing technology of hot tandem mill, from the early 1980's it carried out technological learning and imitation through 'inviting in' (introducing foreign technology into the firm) and 'going abroad' (sending technical staff to train overseas), 'learning by doing' and 'learning by using'. For example, in order to complete the 3050mm hot tandem mill with SMS, Co., in 1985-1987 CNEGC sent over 30 technicians to Germany to participate in over-all project design, implementing scheme design and construction design. As a result, CNEGC completed design drawings at a higher product level than the contract. Through efficient technological learning and imitation, CNEGC accumulated strong manufacturing capabilities in hot tandem mill; meanwhile, through absorbing the mature and even cutting-edge technology of foreign firms, it reduced much time and financial cost in the development of process technology. Most importantly, through a different path ('learning by doing and imitation' instead of 'first-mover innovation'), it managed to reach the leaders' previous position at an earlier time point and shortened the technology gap.

For a long time, foreign multinationals have safe-guarded the hot coil box technology which is key in continuous rolling strip ASP short-flow production line. It was vitally necessary for CNEGC to break the technical blockage and become the one-stop contractor (i.e. from product design, manufacturing, adjustment to installation) in the field of hot

tandem mill. In order to do so, CNEGC set up a hot coil box project team. With years' effort, it developed the first generation of hot coil box by itself in 1999. Then it achieved timely intellectual property (IP) protection by patenting it in China. At the same time, the hot coil box technology has further updated and a more advanced coreless conveying-type technology has emerged. Coreless conveying-type technology was the latest in the world and was hard to develop. CNEGC set up a coreless conveying-type hot coil box project team and in 2001 successfully developed a new product (the current state-of-the-art) using this technology through repeated research as well as revision of technical plans (It again patented it). The success of coreless conveying-type hot coil box solved the bottleneck problem of Chinese metallurgical industry, which in the past required heavy investment due to the long production line, large temperature difference between the head and tail of 'embryonic strip', and unstable quality. Meanwhile CNEGC was able to make a price 30-40% cheaper than imported coil boxes. Due to such technological success and the indigenous IP, CNEGC gradually took over foreign firms' role as one-stop contractor in this field. From 2000 to the end of 2006, its hot rolling strip steel projects with patented hot coil box technology created an output value of 2.479 billion RMB.

3.4 Conceptual framework for the development of technological capability in CNEGC

The conceptual framework for the development of technological capability in CNEGC from 1979 to 2007 is shown in Fig.11.

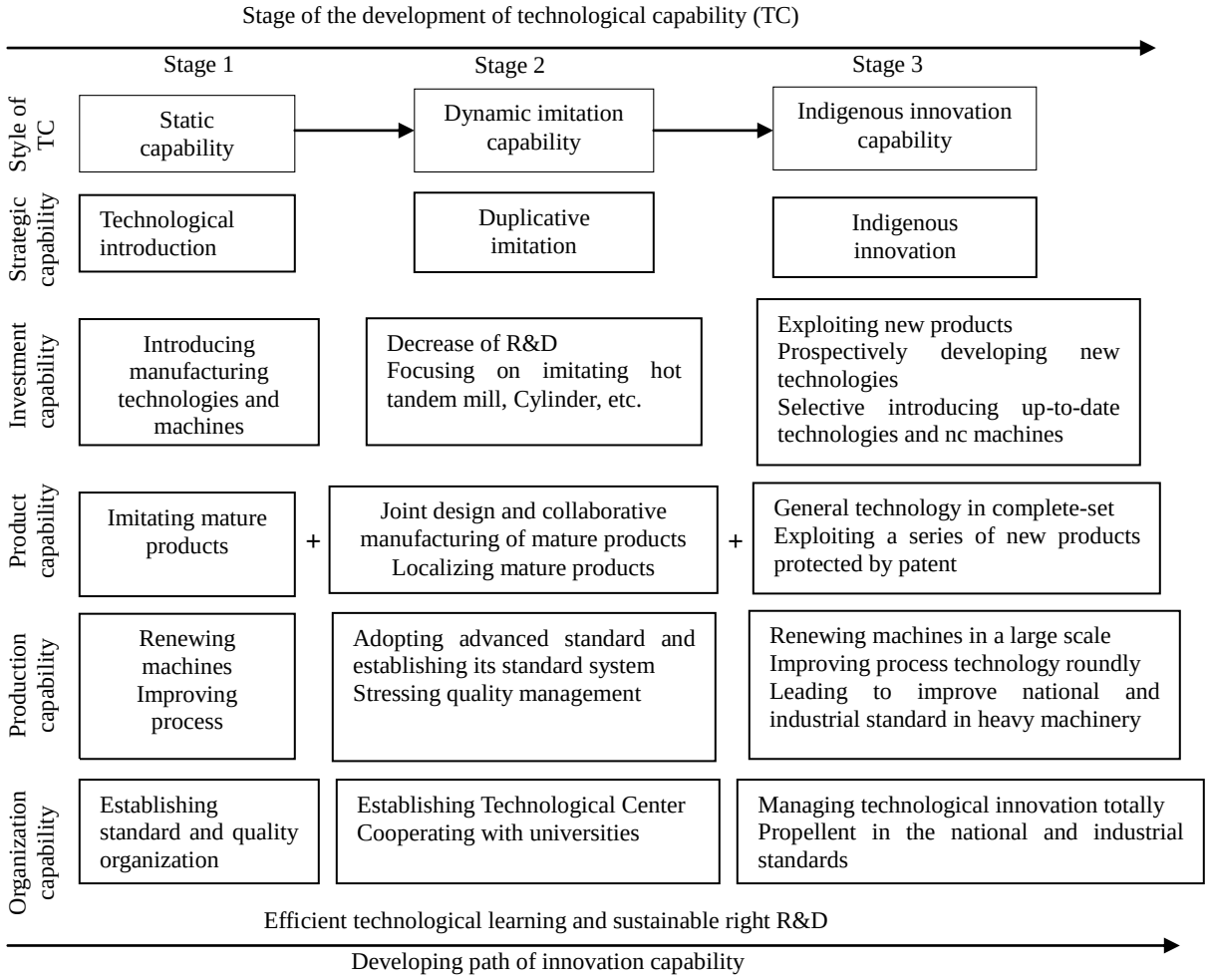

Fig.11 Conceptive framework of the development of technological capability in CNEGC, 1979-2007

4. Explanation of technological capability evolution in CNEGC from the corporate governance perspective

4.1 **Large-scale SOE prioritised to "introduce technology"**

As section 3.2.1 describes, since 1979 CNEGC acquired large quantity of advanced foreign technology and equipments through licensing trades. Meanwhile, by assimilating and localising the introduced technology and equipments, it managed to make significant improvements and upgrades to its technology and products. After nearly one decade of technology introduction and assimilation CNEGC had built up strong manufacturing capability. Its process technology at the same time was continuously uplifted through technology transformation, ensuring the firm a fair sales and profit performance in the competitive market environment.

From the point of CG&F, three elements have contributed to the success of CNEGC's 'technology introduction':

- The ownership type of large-scale SOE. CNEGC was under the supervision of First Ministry of Machinery (FMM) at the time of establishment. In January 1979, approved by the State Council, FMM started to 'open up' CNEGC as the first batch for international trade. It is the firm's large scale and its important role in supporting the nation's economy that has brought it such privilege.
- The reduction of governmental intervention in SOEs' operation and the adjustment of managers' assessment criteria and methods. Under the planned economy, the state determined every detail in the plan and production of CNEGC, the firm's function has been reduced to that of a workshop. Following the reduction of state quota, the firm was increasingly faced with market competition and the need to profit through meeting changing market demand. There is hence an urgent call for governance reform. The year 1984 saw the Ministry of Machinery implementing 'firm director responsibility system' (*Changzhang Fuzezhi*) in CNEGC. It is the first time that top managers are empowered to have control over its operations and responsible for its profit and loss – a far cry from bureaucratic orders under the planned economy. Matching such change was the organisational restructuring. In the same year CNEGC reorganised its workshops and supporting units into economic entities (8 branches and 7 subsidiaries), the branches were responsible for its main businesses and the subsidiaries for sideline businesses. A two-way responsibility and profit distribution system was established between headquarter and the branches. According to a regulation issued by the State Council in 1986[5], CNEGC entered into a four-year fixed profit responsibility contract with the local city government, in which the firm was committed to progressive profit submission. Two years later, another contract was signed between the two about staff wage fund (for the first time associated with the actual profit) from the government. From then on the firm was run under contracted managerial responsibility system. Meanwhile, the form of internal resource allocation changed from distribution according to productivity to ditto of profitability. Profit replaced production as the key indicator of managers' performance. In this stage CNEGC experienced separation of

[5] The Regulation about Deepening Enterprise Reform and Enhancing Enterprise Dynamism (1986, 103).

ownership and control and the adjustment of assessment criteria, which in combination freed the firm from total dependence on state plan. It started to focus on meeting the dynamic market demand. Through introduction and assimilation of foreign technology, it managed to understand and follow the trend of technological development in the industry. Most importantly, the firm did not content with the imported technology and equipments, instead it strived to carry out duplicative innovation in certain areas of process technology and product development.

- Strong financial support. Since 1983 all SOEs needed to take bank loans for their working capital instead of entire reliance on government subsidies, and since 1985 the funding scheme of firms' fixed asset investment was changed from governmental subsidy to loans. These changes mean that firms were no longer entitled to 'free lunch' when it comes to finance. However, during this period the state-owned banks were functioning as specialized banks (meaning the banks acted as investment channels for governments at different levels according to different industries, and their financial decisions were made administratively instead of commercially), as long as the state approved, CNEGC was always guaranteed with money for its technology introduction.

4.2 Technological development constrained by shifting governance at Stage 2

From 1990 CNEGC started to reduce its technology introduction drastically, and its technology strategy changed from introduction to imitation with a focus on the imitative development of large castings and forgings, together with independent R&D of products for metallurgical production lines. It indicates that CNEGC has been gradually upgrading from the stage of static capability to duplicative imitation capability. However, as mentioned in section 3.2.2, during this period the firm was not actively engaged in technological imitation and learning and its R&D investment decreased. Coupled with stagnated process improvement and equipment renewal, its technological development slowed down and its performance fluctuated frequently and worsened. Besides the adverse industrial environment, the firm's shifting CG&F failed to provide the appropriate support for its technological development. On the contrary, it curbed its path to innovation capability cultivation through imitative learning.

The ownership type and structure of CNEGC did not experience any superficial change; however, the *de facto* mechanism has been shifting within the frame of 'state-ownership'. The state as an abstract legal entity could not execute its property rights, hence it delegated to various governmental departments and ministries at different levels. In such context, any organisational change in the governmental authority (removal or merger of departments, adjustment of administrative function, etc) could and have caused shifting ownership of the SOEs. This has also been the case for CNEGC. It belonged to the FMM at the time of establishment; and to the Provincial Bureau of Machinery between 1968-78; and then to 'dual leadership by central and local governments, with FMM in charge of administration'; and until 2000 its profit was collected by the city government while the Ministry of Finance overlooked its finance. The government agents, not knowing how long they would have to look after the firms, were hence discouraged to understand and engage in the development closely; therefore it has been impossible for them to understand the industry, the technology, or the market to develop appropriate technological strategy.

As for management incentive scheme, CNEGC displayed three characteristics:

- The firm had to meet both short-term profit targets and social obligations. Managers'

performance evaluation was based on the single criteria of short-term profitability. For instance, in 1989, the firm signed with the local city government a profit responsibility contract in which it was also committed to progressive profit submission until 1995. Annual assessment based on year-by-year profit had a direct effect on the short-termism of CNEGC's management and its operation. On the other hand, the firm acted not only as a business but also a community – it ran its own schools, hospital, police station, etc.

- Separated management selection and assessment. The quasi-official status of Chinese SOE managers means a long-standing separation of management selection and assessment (Xiao 1998; Xiao&Tang 2001). Since 1979 CNEGC's chief executives have been appointed by the administrative ministry; from 1999 its top managers were decided by the central government. However, performance assessment was done by the city government with which the firm has an operational contract. The Ministry of Finance took over the function when it started supervise the firm in 2000.
- Lenient 'relocation' to a similar position has been the major form of punishment for badly performance managers. Moreover, income roof and ceiling for managers allowed little space for financial reward and punishment.

Financially, the firm also experienced hardship owing to poor sales and credit history. Moreover, from 1989 on the government attempted to remedy the overheated economy and tightened its fiscal and monetary system. CNEGC suffered from shortage of capital as well as cash flow problem in the time of need for expansion. Especially, in 1995 Commercial Bank Law of the People's Republic of China was promulgated. It transformed the specialized banks before into commercial banks, which focuses on the safety, liquidity and benefit of their funds as financial corporations instead of the investment channels for government. It was the functional change of the banks that caused CNEGC was faced with worst financial situation when its performance was volatile. By 1995 it was even unable to pay its utility bills in full and the default further extended to wage payment. At certain stage it had to collect money from its employees (semi-compulsorily) to pay for the necessary equipments.

Therefore, during Stage 2 which the competition became increasingly fierce, the shifting ownership caused lack of the incentive for managers to implement technological innovation. The short-term profit-oriented assessment criteria and the separation of management selection and assessment mechanism and non-economic penalties caused short-termist management and constrained the space for sustainable technology strategy. Technological imitation and process improvement were mainly subject to immediate manufacturing needs. Moreover, multiple social obligations dispersed its limited finance and other resources. Altogether, it is shifting corporate governance and poor finance that have played a crucial role in its stagnant technological development and poor performance.

4.3 Innovation capabilities benefited from improvement in corporate governance

As mentioned in section 3.2.3, CNEGC started to increase its R&D budget since 2001. In order to support the firm's ambition to become 'the world-known base for complete-set equipment' and 'the internationally-renowned base for castings and forgings', it implemented systematic strategic plans for technological development. From 2001 to 2007, its endeavour was reflected in: exploiting a series of new products protected by patent, equipment renewal and modification centering on the exploitation of new product in a large

scale, expansion of product line, replacement of foreign firms' leading roles to take charge of general technology in large-size complete-set equipments, pre-research of related cutting-edge technologies, etc. Its sales revenue and profit were also going up steadily. Apparently it is on a right track to transformation from technological imitation to indigenous innovation. During this process improved corporate governance and finance have played a significant and positive role.

In the aspect of ownership structure and function as a film, CNEGC experienced three significant changes: (i) it converted around 597.59 million RMB of its debt from two state assessment management firms into equity shares and set up a joint venture with them. All of CNEGC's major businesses were taken over by the new firm in which CNEGC dominated the shares as well as senior management posts. The joint-venture had its own shareholders' meeting, board of directors and supervisory board, where 'one-share-one-vote' system was used. Boardroom seats were allocated according to shares, and the posts of CEO, COO were decided as per firm constitution. Through debt conversion CNEGC established a formal structure of governance. We can view this as an indirect improvement of its governance practice and one step towards ownership diversification. Moreover, this debt-to-equity swap greatly improved its capital structure. (ii) In 2002 CNEGC started to restructure the ownership structure of its six subsidiaries and transformed them into minority-state-shareholding enterprises. (iii) In 2003 it corporatized all of its non-profit operations. Such move relieved the firm from its social and political obligations.

Since 2004, SASAC (State-owned Assets Supervision and Administration Committee of the State Council) replaced different ministries and acted as the only ownership agent of SOEs directly under central government. In January 2006 the revised Company Law introduced several meaningful changes. (i) In the revision, SASAC's role as legal agent was confirmed for the first time, which secured its long-term ownership and provided the necessary time to implement strategic policies and engage with the firms. (ii) The law empowered SASAC to appoint and remove Chairman of the board, the board of supervisors and CEO, which for the first time united the function of assessment and selection. (iii) SOEs now have the right to reward managers with firm shares, which can be traded during their service term. This means that stock option incentive is introduced to Chinese SOEs. It will hopefully motivate the top management to focus on the long-term development.

Table 5 Portfolio of performance assessment in central enterprises by SASAC

Financial Performance (70%)						Managerial Performance (30%)	
Content and Weight (%)		Basic indices	Weight (%)	Reference indices	Weight (%)	Assessment item	Weight (%)
Profitability	34	Net asset earning ratio	20	Sales profit rate	10	Strategic management	18
				the surplus cash cover ratio	9		
		Return on asset	14	Profit/cost of capital (EVA)	8	Development and innovation	15
				Rate of earnings on equity	7		
Asset quality	22	Total asset turnover	10	NPL ratio	9	Operational decisions	16
				Current asset turnover	7		
		Acct. receivable	12				

		turnover		Cash/asset ratio	6	Risk management	13
		asset/liability ratio	12	Quick ratio	6	Basic management	14
				Cash ratio	6		
Debt risk	22			Ratio of liabilities to interest	5	Human resource management	8
		Paid interest/debt	10	Contingent liability ratio	5		
		Sales growth rate	12	Sales profit growth	10	Influence in the industry	8
				Growth rate of total asset	7		
Operational growth	22	Ratio of value maintenance and appreciation of capital	10	Technical input ratio	5	Contribution to society	8

Meanwhile, performance assessment and reward/penalty system in SOEs has undergone significant changes – from singular standard (profit) to a portfolio of criteria; from assessment of operational results to the combined evaluation of results as well as process; from separated evaluation and reward to performance-based incentive scheme; and from annual profit evaluation to the inclusion of general performance in service term (3 years). These changes provided managers incentive to seek development through enhancement of technological capability. The year 2003 saw the implementation of two important statutes for SOE performance evaluation which applies to its Chair (and vice Chair) of Board, directors, CEO, COO and CFO. Senior managers are evaluated on the basis of annual as well as service term performance. Also, as Table 5 shows, 'technical input ratio' has become one of the financial criteria. Meanwhile, 'Strategic management' and 'Development and innovation' are assessed for managerial performance. Therefore, the desire to encourage managers to develop technological capability is reflected in the portfolio.

As argued above, adequate finance is crucial for large-scale indigenous innovation and technology transformation. In order to support its technological innovation, CNEGC tried hard to improve it financing capacity and expand its funding channels. Its endeavors are reflected in three aspects: (i) CNEGC utilized the policy to develop the west and acquired funding from central and local government investment projects. (ii) It expanded its source of funding from 5 state banks to 13, including joint-stock banks since 2004; the forms of funding were also changed from total reliance on loans to bill finance, factoring, letter of guarantee, letter of credit, etc. (iii) With the increase of sales and profit, its internal financing capacity also improved.

4.4 CEO plays a key role in innovation capability development

Last but not least, CEO's global vision and aspiration have been key in developing its innovation capability in CNEGC.

The right guy was picked and given the time needed to implement appropriate strategy. In November 2001, Mr Shi Ke, a rising star from within the firm was promoted to CEO. Before that, Shi had worked in CNEGC for more than 20 years and acted as vice general manager for 10 years. As a firm insider with both industrial and organizational expertise, Shi knows very well what he needs to do and where CNEGC should go. Moreover, with the improved corporate governance in SOEs he was given time to do it. Soon CNEGC set a

new agenda to develop new products: “the firm’s top priority is development, and the key to development is to develop new products that are technological advantageous and commercially successful.” (Shi, 2001).

Shi next developed and implemented mid- and long-term strategic plans of CNEGC. Accordingly, the firm started to pay more attention to integration of internal and external resources for nurturing technological capability. Through developing complete product lines and taking charge of general technology in large-size complete-set equipments (instead of relying on foreign multinationals) CNEGC cultivated firm-specific and sustainable competitive capabilities. 7 years on, although it is too soon to claim victory, we can still see significant improvement in both product and commercial terms as shown section 3.

Shi realised the urgent need to progress from duplicative imitation to indigenous innovation, from low-end product to high-technology mix, and from joint (dependent) design/production to self-reliant innovation. He pointed out that technological capability is not like ordinary commodity which can be purchased physically. It has to be developed from within and accumulated from hands-on experiences. Based on such vision, on the one hand CNEGC engaged in active learning and absorption of introduced foreign technology and consolidated its leading position in the generic product market. Meanwhile, it took the challenges to enter new technology field, such as equipments for clean energy projects and large-scale petrochemical industry. Moreover, through overseas organisational mergers and acquisitions and strategic alliances, it orchestrated and channelled external resources into the firm to enhance its technological competitiveness. By setting up an international-networked R&D centre, it aimed to realise highly indigenous innovation capability in heavy machinery industry.

Shi also acted on improving institutional environment for the development of innovation capability. He initiated and supervised the improvement of corporate governance in CNEGC and engaged in expanding financial channels and avoiding the financial risks. Just as discussed in the previous section, all of these efforts paid off, not only technologically, but also financially.

5. Conclusion and Policy Implication

This paper set out to explore the efficient evolutionary path of technological capabilities in China’s SOEs and to examine the role of institutional factors, particularly corporate governance (in the broadest sense) in technological development. In order to do that we depicted the three stages of technological capabilities in CNEGC in the past 30 years, and showed the connection between technological capabilities and firm’s commercial performance in each stage. It also gave two examples to show the efficient path that CNEGC deployed to build innovation capabilities from technological dependent introduction and duplicate imitation. Furthermore, this paper examined the 30 years’ changes of CG&F in China’s SOEs to explain how CG&F affected technological development, especially the development of innovation capabilities. The conclusions are:

(i) There is strong correlation between technological capability and commercial performance in CNEGC. At the first stage, it took advantage of the dominant opportunity of opening up and acquired some manufacturing capability through technology introduction,

and hence improved its sales. Thanks to such manufacturing capability, at stage 2 CNEGC's sales remained stable through collaborate manufacturing with foreign firms. However due to stagnant capability development it constantly suffered loss. At stage 3, it focused on the development of new products and innovation capabilities. Meanwhile, it paid more attention to equipment modification and renewal to further enhance it manufacturing capabilities. With these efforts, CNEGC has acquired sustainable performance record.

(ii) The two examples in CNEGC show that, 'Introduction-imitation-innovation' can be a successful pattern for 'latecomers'-China's SOEs to improve their technological capabilities. More specifically, they can develop dynamic innovation capabilities through efficient technological learning and sustainable right R&D.

(iii) Till 2001, the corporate governance and institutional arrangement of SOEs' did not stimulate technological development. Contrarily, due to shifting governance agenda, flaws in management selection and assessment, soft 'human resource constraint', and lack of finance, SOEs were not actively engaged by their shareholders, nor do the managers have the incentive and time to develop technological capability. Since 2001, along with the improved assessment criteria and management selection, especially after the revision of Company Law in 2006, the corporate governance of SOEs became more systematic and efficient. It gave SOE's managers the incentive and longer-term horizon to formulate appropriate technology strategy. It is likely that the latest progress in dynamic technological development in some SOEs can be explained by these changes.

(iv) CEO's global vision and aspiration can play a decisive role in technological development, especially in guiding the firms out of the vicious cycle of dependent introduction and static capability growth. This role however, has to be conditioned by the situation of SOE corporate governance in China.

The policy implications are clear-cut. With China's WTO membership and commitment to fair-play, government protection through monopoly is no longer viable. Competitive advantage has to be acquired through development of dynamic technological capabilities. Policy makers should think and work about how to utilize corporate governance mechanism to address the challenges of latecomers' technological change – understand the firms, encourage shareholders' engagement, measure and reward (sustainable) progress, and last but not least, choose the right person and make them think long.

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